Effectiveness of Wastewater Purification with Watermelon Seed Chaff

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RESEARCH ARTICLE

ABSTRACT: Watermelon seed chaff was used to treat industrial wastewater from a paint industry. The packed bed filtration method was adopted, as the effect of the bed height, together with the adsorbent particle size were monitored. Adsorbent particle sizes of 1.18mm, 0.60mm and 0.125mm were used to pack the glass column at varying heights of 4cm, 6cm, 8cm and 10cm, while 100mls of the wastewater was filtered through the packed bed for each of the twelve cases. The time taken for the filtration, the volume of the treated water recovered, and the volumetric flow rates were all recorded. In the end, the analysis of the water quality test parameters show that the filtration through the smallest adsorbent particle size of 0.125mm packed to the highest height of 10cm had the greatest effect on the wastewater purification by bringing most of the test parameters closer to the permissible limits; giving pH value of 7.00 which is within the Federal Environmental Protection Agency (FEPA) permissible limit of 6.9; Temperature value of 25.3[0]C within the limit of 20 – 30[0]C; Turbidity result of 201NTU as against the FEPA limit of 250NTU; Conductivity value of 52µs/cm against the specified value of 200µs/cm; TDS and TSS values of 33.8mg/L and 200mg/L against the specified limits of 50mg/L and 250mg/L respectively; and Calcium, Iron and Zinc values of 0.40ppm, 0.07ppm and 23.07ppm which are all within the specified limits of 0.75ppm, 0.3ppm and 50ppm respectively. It is inferred that filtration of wastewater through a packed bed of watermelon seed chaff is a good method of wastewater purification and can be adopted on an industrial scale.

KEYWORDS: Wastewater, water purification, filtration, watermelon seed chaff, packed bed

1. INTRODUCTION

The activities of industries such as those of bleaching, mining, printing, electroplating and metallurgical industries, textile and dye producing industries are among the major industries that have a problem of water contamination [1]. Unlike the biological or organic pollutants which are bio-degradable, heavy metals like Nickel (Ni) and Chromium (Cr) are non-biodegradable [2]. This makes them a source of great concern. Heavy metals accumulate in living organism to a level that causes toxicological effect. Human health and the entire ecosystem are at great risk, unless the water and land systems are effectively managed. For example, the dye industry is one of the known largest industries that consume water. And the effluent coming out of the dye industries is known to contain various metallic

compounds, chemical compounds and colouring compounds, which require adequate treatment before discharge into any available water body [3].

However, dye-laden effluents are very difficult to treat to a satisfactory extent because they are highly varying in composition, unlike other industrial wastewaters that can be treated easily because they are just contaminated in some ways, by either anthropogenic, industrial or commercial activities prior to their release into the environment, or its reuse [4].

Though most industries produce some form of wet wastes, the recent trends in developed technologies would be either to minimize such production, or recycle the waste within the production process. However, many of the

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industries, like dye and textile industries, still remain dependent on such processes that yield wastewater [5]. Wastewater from textile industries contains variety of polluting substances, including dye [6]. Colour is usually the first contaminant to be recognized in the wastewater, and should be removed before discharging the wastes into the water bodies or onto the land. The presence of very little amounts of dye in water is quite visible, and it affects the aesthetic merits, the transparency of water and the solubility of gas in lakes, rivers and other forms of water bodies [7,3]. Colour removal from water is often more important than the removal of soluble colourless organic substances, that usually contribute to the most friction of biochemical oxygen demand (BOD) [8].

The techniques for treating dye wastewater are of different types, stages, and processes. This can sometimes be divided into primary, secondary and tertiary treatments. Tertiary treatment can also be called polishing, but this is usually used for non-biodegradable substances found in industrial wastewater (such as dye), and some inorganic polymeric substances [9]. Primary treatments generally consist of screening, equalization, neutralization, clarification and chemical treatment. Secondary treatments generally consist of biological treatment and removal of metallic compounds, while tertiary treatment consists of the decolouring of the wastewater [2].

In dye-laden wastewater, adsorption process is commonly used to extract the complicated compound out of the wastewater for better use or disposal. Adsorption has found to be one of the most effective physical processes for the treatment of textile wastewater, and the most commonly used adsorbent for colour removal is activated carbon [10], and this is because of its capability for efficiency, adsorbing a wide range of different type of adsorbates [11]. However, its use is, also, limited because of its scarcity and high cost. Several researchers have studied the use of alternative materials, agricultural, forest, animal and several other low cost industrial by-products like peat, wood, tree, and so on, [11,12,9]. Activated carbon adsorption systems, despite being widely used, are expensive, and their regeneration cost is also high. Therefore, their use in wastewater treatment is not necessarily economically feasible, thereby necessitating the need to study and identify the adsorptive characteristics of low cost alternatives. The use of non-conventional adsorbents, particularly those that can be easily regulated, to replace activated carbon in the removal of colour from dye wastewater has been recently proposed.

2. MATERIALS AND METHODS
2.1.1. Sample/material collection and preparation
The industrial wastewater sample used for the experiments was collected at NICEN Paint/Chemical Industry, located at Adielu Crescent, in Osisioma Ngwa LGA, Aba - Abia State of Nigeria. As described by Menkiti*et al.* [14], the sample was collected from the wastewater discharge terminal of the factory, in a ten liter well labeled plastic container and made available for the laboratory tests. The water melon seed chaff was obtained from the laboratory as a leftover experimental material (i.e. after extracting oil from the seed). The chaff was sun-dried, properly ground, and then separated into three mesh sizes of 1.18mm, 0.60mm and 0.125mm respectively.

2.1.2. Equipment/materials used for the experiment
The instruments used for the experiment are as follows: An atomic absorption spectrophotometer (Model: 2010VGB), (Make: Buck scientific), multi-parameter bench photometer (Model: HI 83200), (Make: Hanna), analytical weighing balance (Model: Adventurer Pro A35), (Make: OHAUS), electro-thermal oven (Model: HG 9023A), (Make: B.BRANC, scientific and instrumental company, England), pH meter (Model: HI 2211), (Make: Hanna), conductivity meter (Make: LABTECH), turbidity meter (Model: HI 93703), (Make: Hanna), resort stand, glass column, 100ml, 250ml, 500ml Conical flasks, 250ml beakers, 100ml measuring cylinder, 50ml volumetric flask, glass funnel, stirring rod, spatula, 100ml plastic bottles, distilled water and deionized water.

2.2.1. Packed bed filtration process
Like the approach adopted by Khadhri*et al.* [15] and Iheanacho*et al.* [16], the packed bed filtration process was carried out with the aid of a glass column mounted on a retort stand. The various particle sizes (1.18mm, 0.60mm and 0.125mm respectively) of the watermelon seed chaff were used to pack the column at various bed heights of 4cm, 6cm, 8cm and 10cm, respectively. The wastewater was then poured

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into the packed bed and the tap head of the glass column released to allow flow of the wastewater within the column, while the stop clock was set to monitor the time of flow of the water through the packed bed. At the end of the flow, the volume of the water collected (i.e that flowed through the bed) was measured and the volumetric flow rate calculated. This was done for the three particle sizes and for the four bed heights, after which the collected/filtered wastewater samples were preserved for physicochemical analysis to evaluate the water quality after filtration.

2.2.2. Determination of physicochemical parameters of the filtered wastewater samples

The methods of Yahya et al. [17] are used in these parameter determinations. The physicochemical analysis of the filtered wastewater conducted involved the determination of parameters such as the pH, temperature, color, turbidity, conductivity/total dissolved solids, and total suspended solids, and the results obtained are presented in Tables 2 to 5.The pH and temperature values were determined using a hand held pH/temperature meter (model: HI98107 -HANNA). The color of water samples was determined using colorimetric platinum cobalt method (at 420nm) with HI83200 multipara meter bench photometer. Turbidity of the samples was determined by photometric method using HACH DR/2010 spectrometer at wavelength of 860nm and programme number 750. The conductivity was determined with the use of a hand held conductivity meter model HI98302 (HANNA).

The total solids are made up of dissolved solids (DS) and suspended solids (SS). Thus, TS = DS+SS. It was determined by drying a clean dish of suitable size at 103-105°C in an oven until a constant weight is achieved, then cooling to room temperature in a desiccator, and noting the weight of the dish. 100mls (as found suitable) of the effluent water sample was accurately pipetted into the dish and evaporated to dryness on a steam bath [17,18]. Afterwards, the outside of the dish was wiped and the residue dried in an oven for about 1 hour at 103-105^{0}C. The dish was quickly transferred to a desiccator, cooled to room temperature, and weighed. Again, the dish was returned to the oven, dried further for 15 minutes, and reweighed after cooling to room temperature. The procedure was repeated until

the weight of the dish plus residue remained constant to within 0.05mg. The total suspended solid was calculated using Eqn (1):

$$\text{Total Suspended Solids} = \frac{mg\ total\ solids\ \text{x}1000}{ml\ of\ sample} \quad [1]$$

2.2.3. Determination of heavy metals

As presented by Mondal & Garg [13] and Vikash *et al.* [6], the working principle of an atomic absorption spectro-photometer (AAS) is based on the analyzed sample being aspirated into flame and atomized when the AAS's light beam is directed through the flame into monochromator, and onto the detector that measures the amount of light absorbed by the atomized element in the flame. Since individual metals have their own characteristic absorption wave length, a source lamp composed of that element is used and making the method relatively free from spectral or radiational interferences. The amount of energy of the characteristic wavelength absorbed is proportional to the concentration of the analyzed element in the sample. The sample was thoroughly mixed by shaking, and 100ml of it transferred into a glass beaker of 250ml volume. The sample was then aspirated into the oxidizing air-acetylene flame. When the aqueous sample was aspirated, the sensitivity for 1% absorption was also observed.

3. RESULTS & DISCUSSION

The results for the test parameters of the raw (untreated) samples, together with those of the water samples treated with the three different adsorbent particle sizes at the various bed heights are given in Tables 1 to 5.

Filtration of industrial wastewater through particulate packed bed remains one of the reliable methods of wastewater treatment in recent times, and has proved to be effective in terms of improving water quality, at least to acceptable levels that the water can be considered harmless to both human and the environment after disposal. The results obtained in this study have shown that treating industrial wastewater with watermelon seed chaff had a pronounced effect on the parameters tested. The treatment with the smallest particulate size (0.125mm) at the highest packing height (10cm) exhibited the best parameter enhancement. Although many other researchers namely Khadhri *et al.*, [15];

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Iheanacho *et al.,* [16] who have worked on packed bed adsorption of wastewater and who have shown that smaller particle sizes of absorbent support better purification, utilized activated carbons made from agro-waste materials while this study applied the seed chaff of watermelon directly without having to convert the materials to activated carbons. Treatment with the smallest particulate size of 0.125mm (at the various bed heights) produced pH values that are the farthest from neutrality. Treatment with the particulate size of 1.18mm, at a bed height of 6cm had the best result (6.96), although all particle sizes and bed height experiments gave pH results that are acceptable and within permissible limits (6.5 – 8.5, by FEPA). Fig.1 displays the foregoing.

Table 1: Result for the packed bed adsorption process

S/N	Sample code	Volume of waste water used (ml)	Time taken	Volume recovered (ml)	Volumetric flow rate (ml/min)
1	SIZE 1, HEIGHT 1	100	3min, 41secs	83	22.53
2	SIZE 1, HEIGHT 2	100	5min, 45secs	72	12.52
3	SIZE 1, HEIGHT 3	100	6min, 17secs	55	8.75
4	SIZE 1, HEIGHT 4	100	6min, 33secs	44	6.72
5	SIZE 2, HEIGHT 1	100	10min,25secs	74	7.10
6	SIZE 2, HEIGHT 2	100	11min,19secs	66	5.83
7	SIZE 2, HEIGHT 3	100	13min,01secs	53	4.07
8	SIZE 2, HEIGHT 4	100	15min,29secs	42	2.71
9	SIZE 3, HEIGHT 1	100	17min,02secs	66	3.87
10	SIZE 3, HEIGHT 2	100	18min,33secs	56	3.01
11	SIZE 3, HEIGHT 3	100	19min,01secs	41	2.16
12	SIZE 3, HEIGHT 4	100	19min,23secs	18	0.93

Size 1=1.18mm, Size 2=0.60mm, Size 3=0.125mm (Particulate sizes)
Height 1=4cm, Height 2=6cm, Height 3=8cm, Height 4=10cm (Packed bed height)

Table 2: The physicochemical parameters of the raw/untreated (control) waste water sample

S/N	PARAMETER	RESULT
1	pH	7.20
2	Temperature, ^{0}C	26.0
3	Turbidity, NTU	429
4	Conductivity, µs/cm	109
5	Total Dissolved solids, mg/L	70.05
6	Total Suspended Solids, mg/L	3100
7	Calcium, ppm	2.15
8	Iron, ppm	1.20
9	Zinc, ppm	34.21

Considering the temperature of samples, the treatment with all sizes and bed heights yielded acceptable temperature results. However, a common trend was noticed in the temperature results for the particle sizes and bed heights. The temperature was observed to increase with particle size and with bed height, respectively. From Fig.2, the plot of the turbidity results

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shows the treatment with the smallest particle size as the most effective, bringing the results closer to the FEPA standard (250 NTU). For the conductivity tests, Fig.3 reveals that the treatment with the particle size of 0.125mm is the most effective. However, the entire results for the tests show that all results are within the FEPA permissible limit of 200µs/cm.

Tables 3 to 5 show for the total dissolved solids, that the treatments with the particle sizes of 0.125mm and 0.60mm produced treated water samples with satisfactory results (under the FEPA limit of 50mg/L), while that of 1.18mm particle size had some results that were higher than 50mg/L which is the permissible limit for the total dissolved solids for water. This can also be seen in Fig.3. For the total suspended solids, a view of Tables 3 to 5 and Fig.5, show that only the treatment with the smallest particle size of 0.125mm yielded samples with acceptable results. Furthermore, the treatment with particle sizes of 0.60mm and 1.18mm had treated water samples with results that are far above 2000mg/L, which is the FEPA acceptable limit. For the heavy metal analysis of the treated waste water, the calcium content of the wastewater was found to be 2.15mg/L. And the treatment with the several particle sizes at the various bed heights gave treated water with calcium contents which fall within the FEPA permissible limit of 75 ppm.

Table 3: The physicochemical parameters of the waste water that passed through particle size 1 (1.18mm)

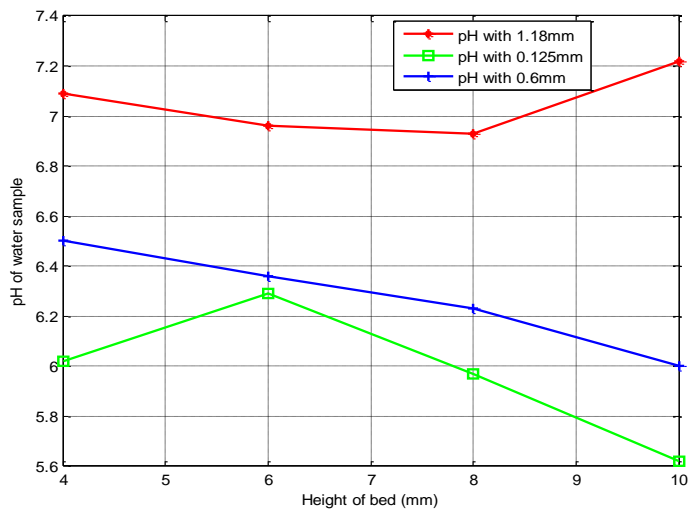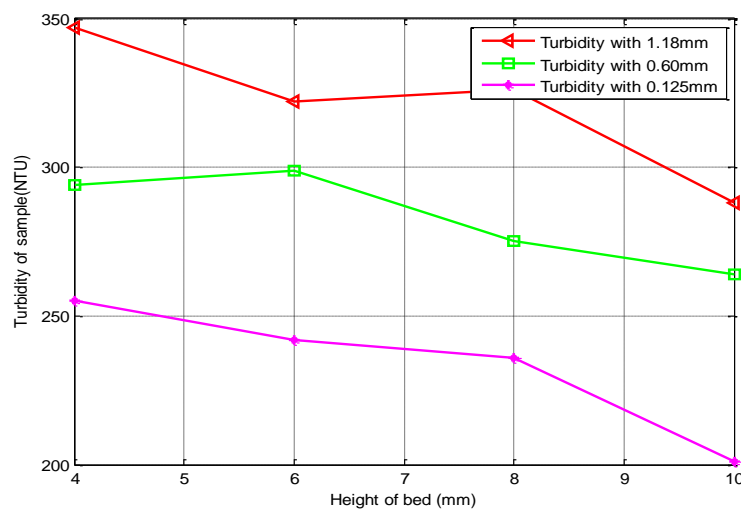| S/N	PARAMETER	Size 1, Height 1	Size 1, Height 2	Size 1, Height 3	Size 1, Height 4
1	pH	7.09	6.96	6.93	7.22
2	Temperature, ^{0}C	23.3	23.5	23.6	23.8
3	Turbidity, NTU	347	322	326	288
4	Conductivity, µs/cm	89	83	70	69
5	Total Dissolved solids, mg/L	57.85	53.95	45.50	44.85
6	Total Suspended Solids, mg/L	1900	1600	2400	2000
7	Calcium, ppm	0.68	0.58	0.40	0.43
8	Iron, ppm	0.30	0.20	0.90	0.40
9	Zinc, ppm	14.04	11.99	16.33	20.12

Height 1=4cm, Height 2=6cm, Height 3=8cm, Height 4=10cm. (Packed bed height)

Table 4: The physicochemical parameters of the waste water that passed through particle size 2 (0.60mm)

S/N	PARAMETER	Size 1, Height 1	Size 1, Height 2	Size 1, Height 3	Size 1, Height 4
1	pH	6.03	6.29	5.97	5.62
2	Temperature, ^{0}C	23.9	24.3	24.6	24.5
3	Turbidity, NTU	294	299	275	264
4	Conductivity, µs/cm	74	76	71	64
5	Total Dissolved solids, mg/L	48.10	49.40	46.15	41.60
6	Total Suspended Solids, mg/L	2800	2700	2600	2300
7	Calcium, ppm	0.47	0.43	0.34	0.36
8	Iron, ppm	0.60	0.70	0.90	1.00
9	Zinc, ppm	27.68	22.77	23.86	20.53

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Table 5: The physicochemical parameters of the waste water that passed through particle size 3 (0.125mm)

S/N	PARAMETER	Size 1, Height 1	Size 1, Height 2	Size 1, Height 3	Size 1, Height 4
1	pH	6.50	6.36	6.23	7.00
2	Temperature, ^{0}C	24.7	24.9	25.0	25.3
3	Turbidity, NTU	255	242	236	201
4	Conductivity, µs/cm	58	55	51	52
5	Total Dissolved solids, mg/L	37.70	35.75	33.15	33.80
6	Total Suspended Solids, mg/L	600	500	300	200
7	Calcium, ppm	0.37	0.31	0.36	0.40
8	Iron, ppm	0.70	0.15	0.11	0.07
9	Zinc, ppm	27.42	24.72	23.38	23.07

Fig. 1: pH against bed height for the three particle sizes

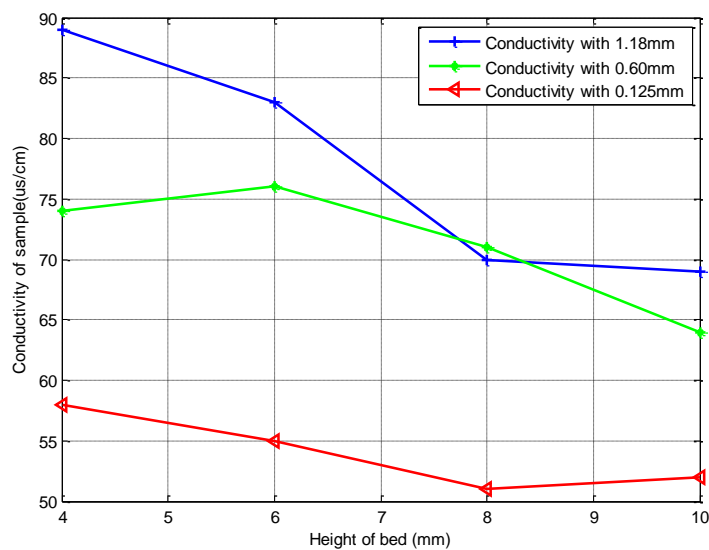**Fig. 2: Turbidity against bed height for the three particle sizes**

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Fig. 3: Conductivity against bed height for the three particle sizes

Fig. 4: TDS against bed height for the three particle sizes

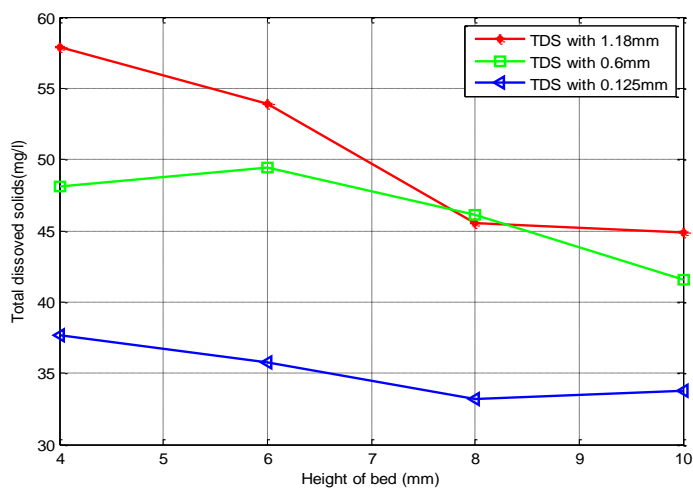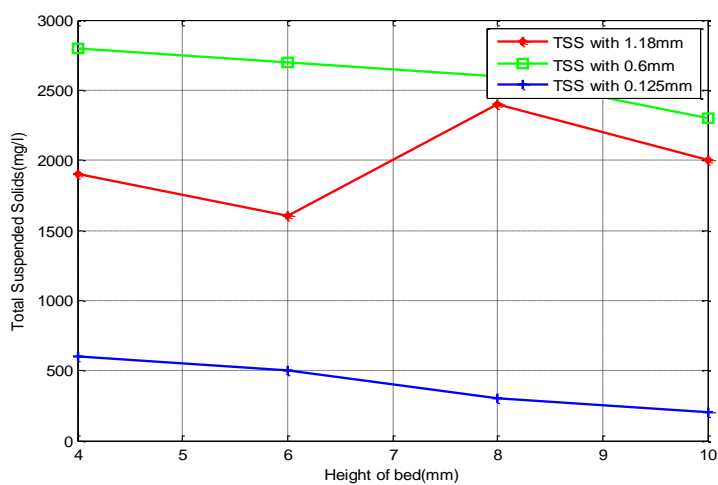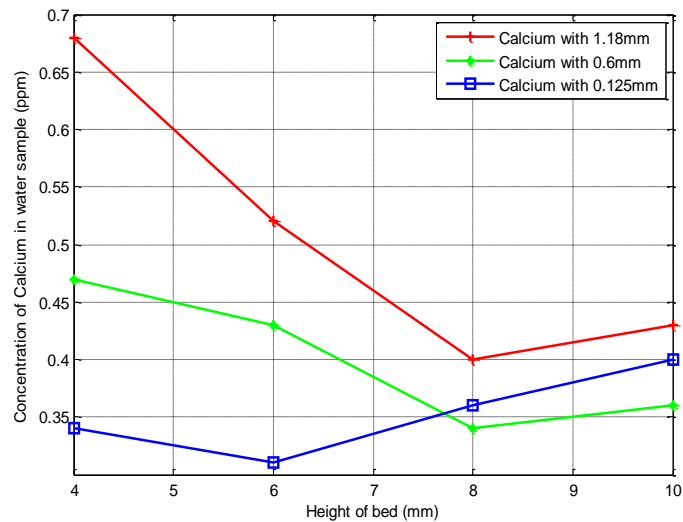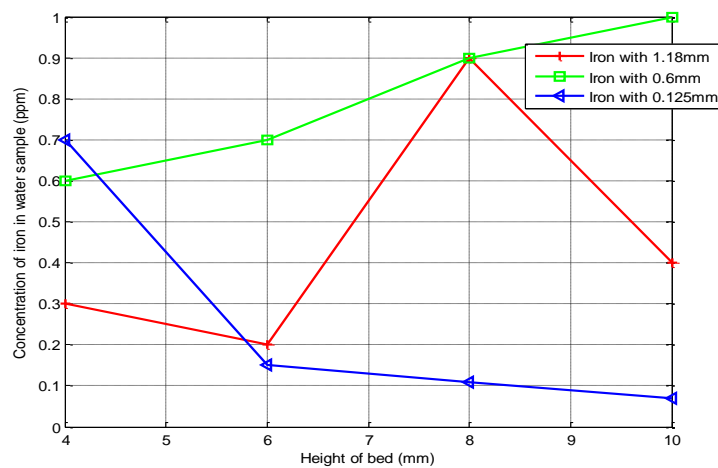**Fig. 5: TSS against bed height for the three particle sizes**

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Fig. 6: Calcium against bed height for the three particle sizes

Fig. 7: Iron against bed height for the three particle sizes

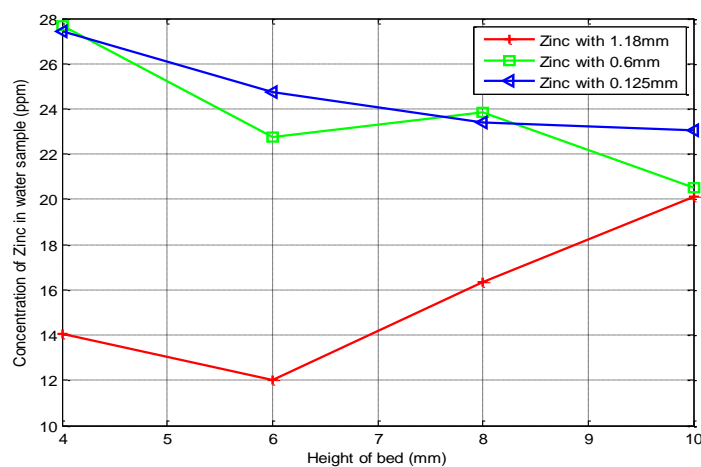**Fig. 8: Zinc against bed height for the three particle sizes**

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For the heavy metals removal from the wastewater, Iron and Zinc were the two parameters considered as they are typical in the heavy metal highlights in the watermelon seed chaff purification potential done by Muhammad et al. [18]. The iron test did not give satisfactory results for the larger particle sizes of 1.18mm and 0.60mm respectively, but gave results that are within the FEPA acceptable limit of 0.3ppm value for water. Both Table 5 and Fig.7 depict this observation. The potential for smaller particle sizes of adsorbents to reasonably remove iron from the wastewater was initially considered by Menkiti et al. [14], while treating brewery effluent using activated *chrysophyllumalbidium* seed shell carbon.

The FEPA standard for the Zinc content of water is 5.0ppm and none of the treatments brought the zinc content of the wastewater to a near acceptable value, as all treatments only brought a slight reduction in the test parameter values, from 34.21ppm value for the raw waste water to a minimum of 11.99 ppm for the treatment with 1.18mm size particle at a bed height of 6cm. This is evident in both Table 3 and Fig. 8. The inability of the adsorbent to remove as much of the zinc ions was first highlighted by Feng et al. [19] which led them to consider using magnetic hydroxyapatite nanoparticles as adsorbent.

4. CONCLUSION

The method of filtration through a packed bed has been a common practice in recent times in the treatment of industrial waste water, and usually the key adsorbents which have been in use include both those of natural origin and others of synthetic sources. In general and based on the results of the experiments, watermelon seed chaff proved to be a good adsorbent in the treatment of the sampled industrial wastewater. The smallest adsorbent particle size of 0.125mm packed at the highest height of 10cm proved to be the best condition for the process, as it was able to bring most of the tested parameters from their distant (from the set limits) values for the raw sample, to within or at least near permissible limits for the waste water after treatment. Thus the use of watermelon seed chaff as industrial wastewater treatment material is highly recommended.

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